Acta Biologica Sibirica
Vol 9 (2023): Acta Biologica Sibirica , 1037–1060
Articles

Assessment of landscape ecological stability in the border postvirgin regions of the Urals and Siberia

Yuriy A. Gulyanov	Orenburg Federal Research Center, Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, 11 Pionerskaya St., Orenburg, 460000, Russia
Alexander A. Chibilyov	Orenburg Federal Research Center, Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, 11 Pionerskaya St., Orenburg, 460000, Russia
Marina M. Silantieva	Altai State University, 61 Lenin Ave., Barnaul, 656049, Russia
Natalia V. Ovcharova	Altai State University, 61 Lenin Ave., Barnaul, 656049, Russia
Lyudmila V. Sokolova	Altai State University, 61 Lenin Ave., Barnaul, 656049, Russia
Yuriy A. Padalko	Orenburg Federal Research Center, Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, 11 Pionerskaya St., Orenburg, 460000, Russia

In the steppe regions of the Urals and Siberia bordering the Republic of Kazakhstan (RK), there is a noticeable spatial dynamics of the land fund structure and the environmental sustainability of the territory, characterized by geographical peculiarities and confinement to international transport communications. The border municipalities of the Orenburg Oblast are characterized by a greater relative size of agricultural lands, agricultural lands, hayfields, and pastures with a smaller share of arable lands, perennial plantations, and non-agricultural lands. The index of landscape ecological stability (ILES, 1.13) is 0.29 p.p. higher than that of the oblast as a whole (0.84) and corresponds to a conditionally stable state. In the Altai Krai municipalities bordering with the RK there is an excess of the regional average relative values for the area of SPNA (specially protected nature areas), pastures, non-agricultural lands and fallow lands, a close share of agricultural land and a smaller share of agricultural land, arable land, perennial plantations and hay fields. The average ILES value (1.08) is 0.09 p.p. lower than in Altai Krai as a whole and 0.05 p.p. lower than in the border municipalities of the Orenburg Oblast. The location of bordering municipalities to international transport communications is accompanied by a trend towards decreasing ILES. To a greater extent, it is connected with the increasing share of arable land in the structure of land, especially in territories predisposed to the production of marginal crops (oilseeds, melons).

Acta Biologica Sibirica 9: 1037–1060 (2023) doi: 10.5281/zenodo.10213047

Corresponding author: Yuriy A. Gulyanov (iury.gulynov@yandex.ru)

Academic editor: R. Yakovlev| Received 29 October 2023 | Accepted 15 November 2023 | Published 30 November 2023

http://zoobank.org/4A99C210-7A71-4EFA-9CE3-EA3211DAAD6C

Citation: Gulyanov YuA, Chibilyov AA, Silantieva MM, Ovcharova NV, Sokolova LV, Padalko YuA (2023) Assessment of landscape ecological stability in the border postvirgin regions of the Urals and Siberia. Acta Biologica Sibirica 9: 1037–1060. https://doi.org/10.5281/zenodo.10213047

Keywords

Post-virgin border regions, Ural, Siberia, land fund structure, environmental sustainability, territory landscape, food safety, land use intensification

Introduction

During Russia's radical economic transformations associated with the reorganization of the agrarian sector of the economy and the introduction of western sanctions, ensuring food security of the population and maintaining the country's grain export potential stimulates the agroindustrial complex to work at a higher pace. Grain farming in Russia has traditionally been a strategic sector of the economy, determining the development of many related industries, as well as food and raw materials markets. The level of its development is often regarded as an indicator of economic well-being and even geopolitical power of the state (Altukhov 2009).

Sustainable development of the grain-producing complex plays an important role in ensuring food security and social stability in many other, including neighboring countries, including former Soviet republics - Ukraine (Materinska 2013; Lopatiuk 2014), Kazakhstan (Mizanbecova et al. 2018; Karatayev et al. 2022), Belarus (Kireyenka et al. 2016; Shundalov 2023) and others. Accelerated increase of grain exports in the world (associated with pandemic and post-pandemic situation, among others), determining the economic prosperity of many countries, USA (Wu et al. 2021; Bruce et al. 2022), EU countries (Pince et al. 2022), Argentina (Merlos et al. 2015), Brazil (Anghinoni et al. 2021; Garbelini et al. 2022), Australia (Simmons et al. 2020), including Russia, which is firmly established in the global grain market, is conditioned by the rapid increase in the world population, limited land resources, and progressive climate aridity accompanied by instability of gross yields (Korotkikh 2019).

According to numerous estimates of various experts, many regions of Russia are experiencing an increase in crop production (Kolodina 2015; Glas'ev 2019). The increase in gross yields of field crops, despite extremely stressful meteorological conditions, primarily in the regions of traditional bread growing, is noted against the background of significant technological reequipment of the industry, successes in breeding and introduction of knowledge-intensive agricultural technologies (Gulyanov et al. 2023). The return to cultivation of arable land, which for various reasons was taken out of circulation in the post-Soviet period, is also important in increasing gross yields. However, the financial condition of the agroindustrial complex of Russia is significantly dependent on the quality of agricultural land. At the same time, the efficiency of agrarian land use and the full use of land resources, which are one of the most valuable natural resources of the country (Chupina et al. 2023), are associated with the formation of infrastructure and geographical location of regions, with their proximity to large agglomerations, logistics routes for purchasing and marketing products, with the development of international transport corridors and transport hubs, especially regions located in peripheral or border areas (Shuvarin and Savrukov 2019; Kuznecova 2020). The same and some other aspects, which have both purely economic and environmental components (Nepoklonov et al. 2018), often influence the structure of the land fund and land differentiation by types of use, which determine the environmental sustainability of the territory of both individual regions and the environmental situation in the country as a whole.

In this sense, one of the most acute environmental problems in Russia, which requires constant monitoring, is the environmental condition of the arid territory of Russia, located mainly on the southern borders of Russia, including those bordering the Republic of Kazakhstan. Its relevance has increased significantly over the last five to six years in the context of increased demand for agricultural products, accompanied by chaotic export of Russian grain from border areas by road transport, directly purchased from agricultural producers for cash. According to various experts, before the restrictions on grain imports by road and sanctions on railway deliveries imposed by Kazakhstan in spring 2023, with all existing tracking systems in place, the volume of such trade transactions at grain hoardings in the eight contiguous territories of the Russian Federation with the border of Kazakhstan reached 3.0 million tons (Kazakhstan extends restrictions 2023). Under the current conditions of trade stimulation of land use intensification, which is expressed in the extremely wide involvement of huge areas of land, including low-productive lands, in cultivation, the problems of forming an optimal structure of the land fund, environmental sustainability of the territory, and development of low-productive lands become especially urgent in the border regions of the Urals and Siberia.

The creation and maintenance of an ecologically safe and sustainable structure of agricultural land use in these regions is one of the top-priority tasks for optimizing the environment and productivity of agricultural land (Zonn et al. 2004), as formulated by V.V. Dokuchaev in the form of developing norms on the optimal ratio in agrolandscapes between arable land, forest land, meadows and water bodies (Dokuchaev 1953). It should be noted that environmental problems associated with ecosystem degradation due to the continuous progress of industrialisation and urbanisation imply the widespread implementation of measures to restore the environment and achieve sustainable development goals not only in our country but also worldwide (Procop 2020; Nikouei et al. 2022; Shao et al. 2024). This is evidenced, for example, by the implementation of integrated management of regional ecosystem protection and restoration in China due to the highly intensive exploitation of land resources and the natural environment, accompanied by ecosystem imbalance and numerous environmental problems that can affect the sustainable development of the country (Wang et al. 2023; Lu et al. 2024). Scientific publications by Chinese scientists point out the dependence of the environmental sustainability of the territory of the regions on the contribution of different types of land use characterized by specific environmental risks (Zhang et al. 2022).

The direct or indirect impacts of land use on ecosystems, expressed in changes in landscape and ecological processes, are observed by US researchers (Akamani 2020; Malanson et al. 2021). They point to the close relationship between ecosystem services and ecosystem resilience and note that ecosystems with low resilience are characterized by greater vulnerability to impacts and lower ecosystem service potential (Eeswaran et al. 2021). The ecological stability of biotic communities plays an important role in the development of sustainable ecosystems in Israel (Parpapov and Gal 2016). Management of environmental restoration and ecological resilience at current levels of degradation is increasingly recognized in Canada (Uprety et al. 2012).

In Germany and Austria, many researchers have noted the negative impact on regional ecosystem services, leading to their deterioration or even collapse, of irrational or high-intensity land use changes due to a lack of attention to environmental sustainability due to overexploitation of land resources (Kastner et al. 2021; Canelas et al. 2022). However, it cannot be overlooked that there is ample evidence to suggest greater freedom of choice in land use development with improved environmental sustainability (Wang et al. 2021). In this regard, the issues discussed in this study concerning the current structure of the land fund and the ecological sustainability of the post-virgin territory in the border regions of the Urals and Siberia are extremely relevant, and the results obtained are of high practical importance. The actualization of this information is expedient from both ecological and economic points of view, paradoxically closely interrelated with each other. For example, preservation of optimal areas of complex landscapes in their natural state, including through the withdrawal of marginal lands from active agricultural turnover, can not only contribute to the maintenance of biological diversity, but also allow to concentrate production resources on the best lands suitable for the development of modern knowledge-intensive agrotechnologies (Kiryushin 2004; Gulyanov et al. 2022).

We assumed that the problem is associated not only with the insufficient study of impact of the borderland on the environmental components of land use in Russia, but also with the strategic importance for both countries to optimize land use in transboundary post-virgin space in connection with the development of international transport (primarily road) communications from the Russian

Federation to Kazakhstan and further to the EAEU countries and far abroad. In this regard, the study of this character is of great relevance.

The purpose of our research was to identify the structure of the land fund and to assess the environmental sustainability of the Urals and Siberia steppe areas adjacent to the Republic of Kazakhstan, considering the Orenburg Oblast and Altai Krai as model regions.

Materials and methods

The object of research was the border steppe regions of Russia (Orenburg Oblast, Altai Krai) and the Republic of Kazakhstan. Data on the structure of the land fund (modern and in dynamics) were collected and analyzed in the context of municipalities (administrative districts) of the Orenburg Oblast (Fig. 1) and Altai Krai (Fig. 2) bordering the Republic of Kazakhstan.

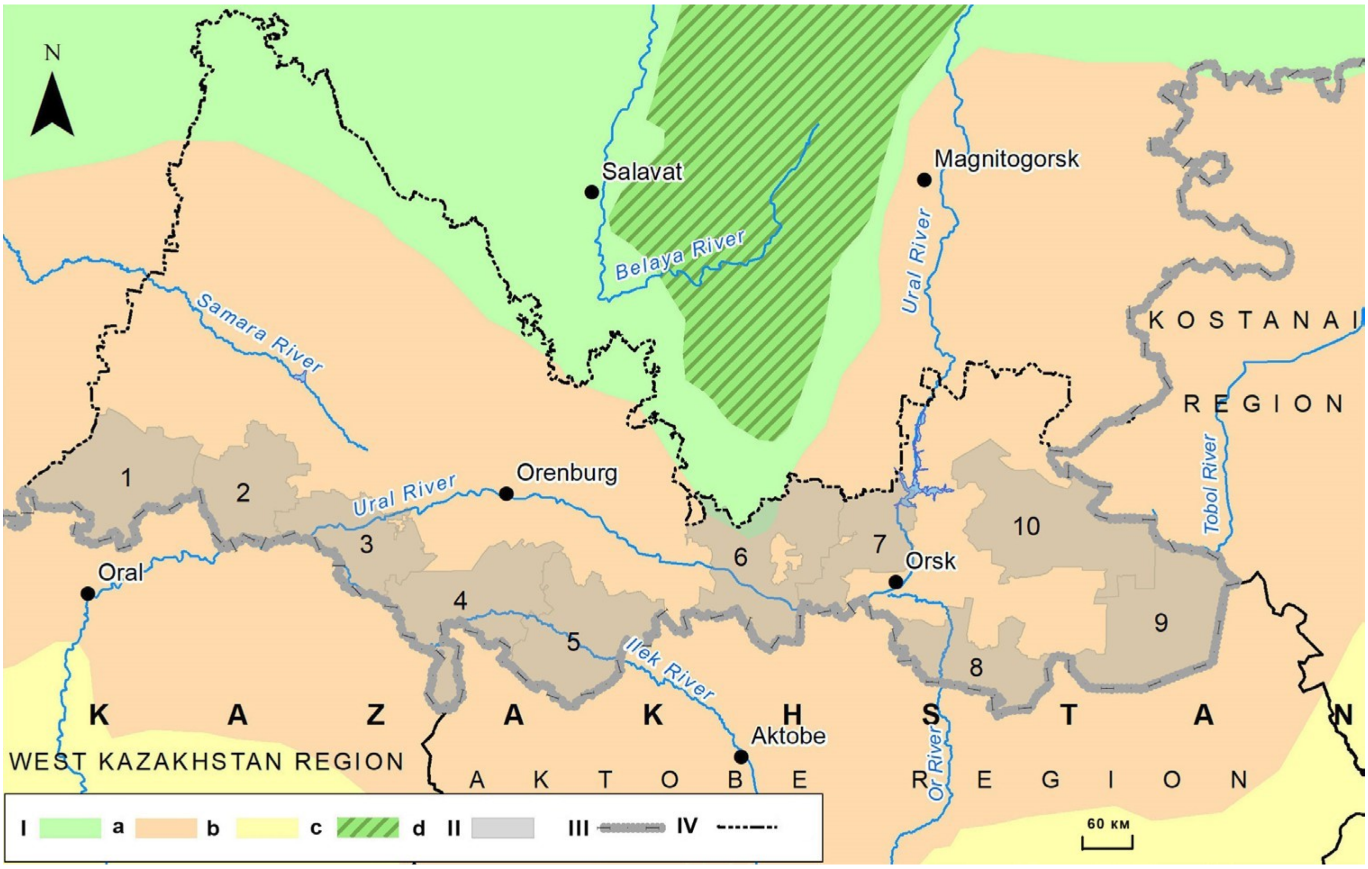

Figure 1. *Spatial visualization of research objects in the border zone of the Orenburg region of the Russian Federation and the RK. I - natural zones and areas: a – forest-steppe zone; b – steppe zone; c – semi-desert zone; d – mountainous forest area; II – municipalities (administrative districts) of the Orenburg region: 1 – Pervomaysky, 2 – Tashlinsky, 3 – Ileksky, 4 – Sol-Iletsky, 5 – Akbulaksky, 6 – Kulundinsky, 7 – Gaysky, 8 – Dombarovsky, 9 – Svetlinsky, 10 – Adamovsky; III – state border; IV – regional borders.*

Data on the structure of the land fund of the Republic of Kazakhstan were analyzed in the context of the regions bordering the Orenburg region (West-Kazakhstan, Aktobe, and Kostanay Oblasts) and Altai Krai (Pavlodar and East-Kazakhstan Oblasts). Analysis of the current structure of the land fund (as of 1 January 2022) was carried out towards land categories. The assessment of environmental sustainability of the territory of the bordering municipalities was carried out by calculating an index of landscape ecological stability (ILES), reflecting the relationship between the natural state of the natural environment and the amount of anthropogenic load. The ILES calculation was based on the comparison (ratio) of the area of the territory occupied by the elements of favorable impact on environmental components and the area of the territory under the elements of negative impact, taking into account methodological developments (Klementova, Geinige 1995; Kochurov 2005; Baranov 2012; Klyushin, Shormanov 2015; Glukhovskaya 2017; Popytchenco 2021) and was carried out according to the formula:

$$ILES = \sum Sfav / \sum Sunfar \quad (1)$$

where: $\sum Sfav$– territory occupied by elements of favourable impact on environmental components, ha^3;

$\sum Sunfar$– territory occupied by elements of unfavourable impact on environmental components, ha^3.

Elements having a favorable impact on environmental components were considered to be areas with natural vegetation (meadows, forests, steppes, fallow lands), their combinations and varieties, including reserves, sanctuaries, protected areas, etc., as well as forests. forest fund. Elements of negative impact were considered to be anthropogenically altered lands under settlements, buildings, road network, open pits and mining sites, waste landfills and dumps, annually cultivated lands (arable land), lands of industry, transport, and communication.

Taking into account the above details, the formula for calculating the ILES is as follows.

$$ILES = (Sh + Sg + Sp + Sw + Snf + Sf + Sl + Sw) / (Sar + Sb + Sd + Slwr) \quad (2)$$

где: Sh – hays, ha^3

Sg – grazing lands, ha^3

Sp – perennial plantings, ha^3

Sw – wooded lands, ha^3

Snf – non-forest fund wooded lands, ha^3

Sf – flooded lands, ha^3

Sl – laylands, ha^3

$Swtl$– wetlands, ha^3

Sar– arable lands, ha^3

Sb– building lands, ha^3

Sd– disturbed lands, ha^3

$Slwr$ – lands with roads and others (industrial, transportation, communications, landfill sites, dumps, and ravines), ha^3.

The ecological stability of the territory was considered to be strongly pronounced at ILES values greater than 4.5 and well pronounced at values of 3.0-4.5. At lower ILES values the state of territory was considered conditionally stable (1.0-3.0), unstable (0.5-1.0), and unstable with good expression (below 0.5). The differentiation of agricultural land by types of use (in dynamics) was analyzed according to the data from the Federal Service for State Registration, Cadastre and Cartography State (National) Report 2022, statistical materials provided by regional ministries and departments, as well as expeditionary surveys data. Statistical analysis was performed in Microsoft Office Excel.

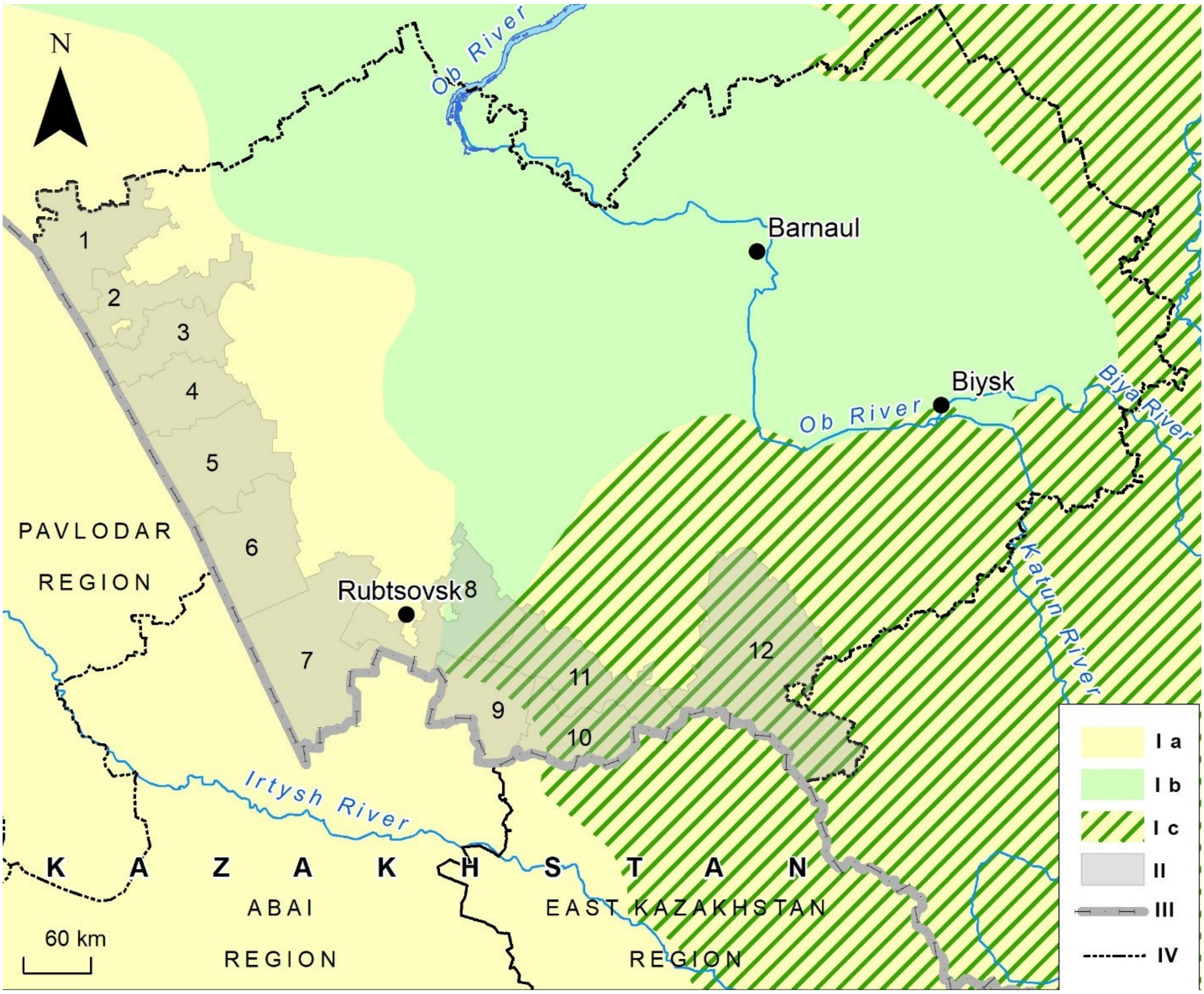

Figure 2. *Spatial visualization of research objects in the border zone of Altai Krai and RK. I – Natural zones and areas: Ia – steppe zone; Ib – forest-steppe zone; Ic – mountain steppe, forest-steppe and forest area; II – Municipalities (administrative districts) of Altai Krai: 1 – Burlinsky, 2 – Slavgorod Municipal District, 3 – Tabunsky, 4 – Kulundinsky, 5 – Klyuchevsky, 6 – Mikhailovsky, 7 – Uglovsky, 8 – Rubtsovsky, 9 – Loktevsky, 10 – Tretyakovsky, 11 – Zmeinogorsky, 12 – Charyshsky District Municipal District; III – state border; IV – regional borders.*

Result

In the structure of the land fund of the Russian Federation and the Republic of Kazakhstan according to the current legislation, there are lands of agricultural purpose, settlements, industry, energy, transport, communications, radio broadcasting, television, and informatics; lands for space activities, defense, security, and other special purpose lands; lands of specially protected territories and objects; lands of forest fund; water fund lands, and reserve lands (State Statistics Service of the Russian Federation).

The results of the statistical data show that the structure of the land fund of the Russian Federation is dominated by forest lands, which occupy an area of 1127.9 million ha or 65.86% of all lands within the administrative boundaries of the country. Agricultural lands occupy almost three times less area (379.7 million ha or 22.17%), and lands of other categories have an even smaller share – 1.04% (lands of industry, energy, etc.) – 1.20% (lands of settlements) – 1.64% (lands of the water fund) – 2.94% (lands of specially protected territories and objects) – 5.14% (reserve lands).

The distribution of the land fund by categories in the Republic of Kazakhstan is fundamentally distinguished by the predominance of agricultural land, which occupies an area of 113.9 million ha or 41.82% of all land within the administrative boundaries of the country (272.5 million ha) and reserve land (32.29% or 88.0 million ha). The share of forest lands (8.23% or 22.4 million ha) is much smaller than in the RF, while the lands of industry and energy, lands of specially protected territories and lands of the water fund have approximately the same share in the structure of land categories (0.82–2.87–1.54%) as in the RF (1.04–2.94–1.64%, respectively).

The distribution of the land categories in the border steppe regions of the Russian Federation and the Republic of Kazakhstan is also characterized by certain peculiarities, consisting of a greater share of agricultural and forestry lands in the border regions of the Russian Federation compared to the adjacent regions of the Republic of Kazakhstan. At the same time, in the adjacent territories of the RK, the greatest area is occupied by the lands of settlements and reserve lands, which account for up to a third and more of the land area within the administrative boundaries (Table 1).

Country, oblast, municipality	Land area by category, ha[3] / share in the total land area within the administrative boundaries, %						
	I	II	III	IV	V	VI	VII
RF, Orenburg Oblast, total	10908.5/88.18	404.3/3.27	253.7/2.05	117.1/0.95	630.7/5.10	24.8/0.20	31.1/0.25
The districts bordering with the RK	4247.9/91.72	58.9/1.27	73.5/1.59	36.2/0.78	185.1/4.00	7.7/0.17	22.3/0.48
RK, West Kazakhstan, total	7755.8/56.74	2288.3/16.74	47.3/0.35	12.4/0.09	217.0/1.59	81.5/0.60	3267.9/23.91
RK, Aktobe Oblast, total	12552.6/42.43	4024.7/13.60	196.5/0.66	1177.5/3.98	221.0/0.75	13.1/0.04	11399.7/38.53
RK, Kostanay Oblast, total	10838.0/55.30	1626.7/8.30	108.6/0.55	742.3/3.79	456.7/2.33	67.9/0.35	5759.9/29.39
RF, Altai Krai, total	11533.9/68.66	384.1/2.29	126.9/0.76	45.0/0.27	4432.8/26.39	195.1/1.16	81.8/0.49
The districts bordering with the RK	2510.23/67.89	48.87/1.32	21.57/0.58	38.55/1.04	1030.90/27.88	43.10/1.17	4.07/0.11
RK, Pavlodar oblast, total	7124.4 /57.13	1832.6 /14.70	121.0 /0.97	357.9 /2.87	126.0 /1.01	78.9/ 0.63	2829.7 /22.69
RK, East Kazakhstan Oblast, total	12256.5 /43.24	2947.1 /10.40	138.3 /0.49	1688.2 /5.96	2153.9 /7.60	571.1/ 2.01	8591.5 /30.31

Table 1. *Distribution of the land fund by land categories in the adjacent steppe territories of the Russian Federation (RF) and the Republic of Kazakhstan (RK)*

Note: I – agricultural lands, II – settlement lands, III – lands of industrial, energy, transport, communication and special purpose lands, IV – lands of specially protected territories, V – lands of forest fund, VI – lands of water fund, VII – reserved lands.

The principal peculiarity of land distribution in border municipalities (administrative districts) of Orenburg Oblast, as compared to similar territories of the Altai Krai territories, is a significantly larger share of agricultural land (91.72 and 67.89%), lands of settlements, industry, energy, and reserve lands (3.34 and 2.01% in the sum), as well as a significantly lower share of lands of specially protected territories, forest and water funds (4.94 and 30.09% totally). Moreover, in the Russian Federation and the Republic of Kazakhstan, land accounting is carried out on the basis of land areas, which includes lands for specific economic purposes and are distinguished by natural and historical characteristics. For example, agricultural lands include lands systematically used for agricultural production, arable land, fallow land, perennial plantations, hay fields, and pastures. Additionally, wetlands (including swamps), forest areas, lands under forest plantations, building lands, roads and disturbed lands are classified as non-agricultural lands (State (National) Report 2022).

Our analysis of statistical data for the Russian Federation indicate the predominance of non-agricultural lands in the overall structure (1490.6 million ha), with a share of 87.04% within the administrative boundaries. Of the agricultural lands that occupy an area of 221.9 million ha (12.96%), 7.16% is arable lands, 3.99% is pastures, 1.40% are hay fields and less than 1.0% each is fallow lands and perennial plantations. Moreover, the land distribution in the Republic of Kazakhstan is fundamentally distinguished by the predominance of agricultural lands (83.52%), occupying an area of 219.6 million ha. Of these, almost 70.0% or 184.0 million ha are pastures, 10.14% (26.7 million ha) are arable land, 1.94% (5.1 million ha) are hayfields, 1.40% (3.68 million ha) are fallow lands, and only 0.06% (0.15 million ha) are perennial plantations.

The structure of land fund in the border steppe regions of the Russian Federation and the Republic of Kazakhstan is also characterized by certain peculiarities, consisting of an approximately equal share of agricultural lands in the Orenburg Oblast and adjacent to its West-Kazakhstan, Aktobe, and Kostanay Oblasts, as well as its significantly higher share in the Pavlodar and East-Kazakhstan Oblasts of the Republic of Kazakhstan, compared to Altai Krai (Table 2).

Country, oblast, municipality	Land area by category, ha^3 / share in the total land area within the administrative boundaries, %						
	I	Among them					VII
		II	III	IV	V	VI	
RF, Orenburg Oblast, total	10810.4/87.39	6104.3/49.35	0/0	22.9/0.19	696.4/5.63	3986.8/32.23	1559.8/12.61
The districts bordering with the RK	3484.56/89.29	1888.21/43.40	0/0	1.9/0.04	346.7/7.97	1647.5/37.87	466.04/10.71
RK, West Kazakhstan, total	13890.4/91.78	567.3/3.75	1013.2/6.69	2.7/0.02	1238.2/8.18	11069.0/73.14	1243.5/8.22
RK, Aktobe Oblast, total	26970.2/89.71	708.9/2.36	501.2/1.67	1.6/0.01	464.4/1.54	25293.9/84.14	1243.5/8.22
RK, Kostanay Oblast, total	18013.1/91.90	6293.5/32.11	223.0/1.14	11.2/0.06	326.8/1.67	11158.6/56.93	1587.0/8.10
RF, Altai Krai, total	10585.7/62.99	6573.1/39.12	265.9/1.58	19.0/0.11	1130.7/6.73	2597.1/15.45	6218.8/37.01
The districts bordering with the RK	2275.0/56.91	1373.6/34.36	118.1/2.96	1.9/0.05	161.3/4.03	620.2/15.52	1722.3/43.09
RK, Pavlodar oblast, total	11172.6/89.56	2032.5/16.29	537.3/4.31	3.1/0.02	302.3/2.42	8297.4/66.51	1302.9/10.44
RK, East Kazakhstan Oblast, total	22629.1/79.90	1502.3/5.30	230.9/0.82	5.8/0.02	1057.0/3.73	19833.1/70.03	5693.5/20.10

Table 2. *Distribution of the land fund by lands in the neighboring steppe territories of the Russian Federation (RF) and the Republic of Kazakhstan (RK)*

Note: I – agricultural lands, II – arable lands, III – laylands, IV – perennial planting lands, V – haylands, VI – grazing lands, VII – non-agricultural lands.

A distinctive feature of land distribution in the border municipalities (administrative districts) of the Orenburg Oblast, compared to similar territories of the Altai Krai, is a significantly smaller share of nonagricultural lands (10.71 and 43.09%), a larger share of arable lands (43.40 and 34.36%), hayfields (7.97 and 4.03%), a significantly larger share of pastures (37.87 and 15.52%), and complete absence of fallow lands. Common for both territories is an approximately equal and very small share of perennial plantations (0.04 and 0.05%). The ILES values indicate its significant

Acta Biologica Sibirica
Vol 9 (2023): Acta Biologica Sibirica , 1037–1060
Articles

variability both in RF and RK, in the neighboring regions of the Urals, Siberia and RK, and in the individual municipalities (administrative districts) of the Orenburg Oblast and Altai Krai (Table 3).

The ILES value indicates a pronounced ecological stability of the territory in the RK (4.94) and a conditionally stable condition in Russia (2.50). More stable ecological conditions are calculated for the territories of the RK regions bordering the Orenburg Oblast and Altai Krai. The highest ILES values are observed in the West Kazakhstan and Aktobe oblasts that border the Orenburg oblast and the East Kazakhstan oblast that borders Altai Krai. With the average value of ILES in the Orenburg Oblast (0.84) and corresponding to unstable ecolocondition of the territory, in the West Kazakhstan and Aktobe Oblasts the territories are characterized by pronounced ecological stability (9.31-7.78), and in the Kostanay Oblast conditionally stable condition (1.81). In Altai Krai, with a slight advantage over Orenburg Oblast in the environmental sustainability of the territory characterized by a conditionally stable state (1.17), the difference from neighboring oblasts of the Republic of Kazakhstan, characterized by a more stable environmental state, is also significant and were 2.58 (Pavlodar Oblast) and 5.17 (East Kazakhstan Oblast).

Country, oblast, municipality	ILES	Country, oblast, municipality	ILES
Russian Federation, total	2.50	Republic of Kazakhstan, total	4.94
Orenburg Oblast	0.84	West Kazakhstan Oblast	9.31
Pervomaisky	0.80		
Tashkinsky	0.69		
Ileksky	0.78		
Sol-Iletsky	0.76		
		Aktobe Oblast	7.78
Akbulaksky	1.37		
Kuvandysksky	1.75		
Dombarovksy	2.11		
Svetlinsky	0.84		
		Kostanay Oblast	1.81
Adamovsky	1.33		
Altai Krai	1.17	Pavlodar Oblast	3.75
Burlinsky	1.35		
Slavgorod City	0.62		
Tabunsky	0.24		
Kulundisnky	0.28		
Klyuchevsky	0.67		
Mikhailovsky	1.20		
		East Kazakhstan Oblast	6.34
Uglovsky	2.47		
Rubtsovsky	0.87		
Loktesvky	0.44		
Tretiakosvky	1.36		
Zmeinogorsky	1.29		
Charyshsky municipality	2.21		

Table 3. *Complex indicator of ecological sustainability of the territory of the adjacent steppe territories of the Russian Federation and the Republic of Kazakhstan*

We determined the dynamics of agricultural development of land resources in the border steppe territories of the Russian Federation and the Republic of Kazakhstan and revealed some intra- and interregional peculiarities (Table 4).

The decrease in agricultural lands area was common for Orenburg Oblast and Altai Krai, which was more pronounced in Altai Krai and amounted to 770.0 thousand ha or 6.5% for 2006-2021. In the

Orenburg Oblast, the negative trend in the agricultural land was almost twice as low and amounted to 362.6 thousand ha or 3.3% for 2006–2021.

Agricultural lands are characterized by highest human press and vulnerability. Thus, the decrease in their area in the Orenburg Oblast totaled 228.2 thousand ha or 63.0% of the reduced area of agricultural land. The Altai Krai was characterized by a greater absolute (340.0 thousand ha) in the area of agricultural land area, although in relative terms it was 18.8% lower (44.2%) than in the Orenburg Oblast. At the same time, there was a noticeable increase in the area of cultivated agricultural land (arable land), which amounted to 245.0-326.0 thousand ha or 3.7-5.5% of their average size, in Altai Krai and in Orenburg Oblast respectively. The main source of their replenishment in Altai Krai were fallow lands (190.0 thousand ha). We assumed that in the Orenburg Oblast the fallow land fund has become the main source of replenishment of the arable land area, as evidenced by the results of expeditionary studies, although there is no reliable official information on its area in this region.

We concluded that the dynamics of other land area within the agricultural lands is less pronounced. The loss of perennial plantations amounted to slightly more than 1.0%, and changes in hayfields and pastures can only be classified as trends.

Country, oblast, municipality		Agricultural lands area, ha^3						
		Agricultural lands	Among them					
			Agricultural lands	Namely				
				I	II	III	IV	V
Orenburg Oblast	Mean	10988.4	10866.7	5899.9	-	23.1	696.9	3976.3
	CV	2.7	1.4	2.5	-	1.4	0.3	0.7
	Fluctuation, ha^3	-362.6	-228.2	326.0	-	-0.3	-0.7	4.0
	SD, %	-3.3	-2.1	5.5	-	-1.3	-0.1	0.1
The districts bordering with the RK	Mean	4253.2/ 38.7*	3896.4/ 35.9*	1782.3/ 30.2*	-	2.1/ 9.1*	353.2/ 50.7*	1653.2/ 41.6*
	CV	1.4	0.9	0.6	-	2.1	0.4	0.2
	Fluctuation, ha^3	-114.8/ 31.7*	-11.6/ 5.0*	112.3/ 34.4*	-	-0.1/ 33.3*	-0.3/ 71.4*	3.3/ 82.5*
	SD, %	-2.7	-0.3	6.3	-	-4.1	-0.1	0.2
Altai Krai	Mean	11806.6	10758.8	6558.8	342.6	19.1	1136.1	2617.3
	CV	2.9	1.6	1.7	21.5	1.4	0.2	0.6
	Fluctuation, ha^3	-770.0	-340.0	245.0	-190.0	-0.3	0.2	3.0
	SD, %	-6.5	-3.2	3.7	-55.5	-1.6	0.0	0.1
The districts bordering with the RK	Mean	2524.5/ 21.4*	2275.4/ 21.1*	1344.1/ 20.5*	149.0/ 43.5*	1.9/ 9.9*	162.9/ 14.3*	617.5/ 23.6*
	CV	1.1	0.1	0.0	18.5	3.0	0.3	0.2
	Fluctuation, ha^3	-66.0/ 8.5*	-1.5/ 0.1*	72.0/ 29.4*	-72.0/ 37.9*	0.0/ 0.0*	-0.1/ 33.3*	-2.7/ 17.5*
	SD, %	-2.6	-0.1	5.4	-48.3	0.0	-0.1	-0.4

Table 4. *Dynamics of agricultural development of land resources in the border steppe territories of the Russian Federation with the Republic of Kazakhstan (2006–2021)*

Note: I – arable lands, II – laylands, III – perennial planting lands, IV – haylands, V – grazing lands, "*" – % from the regional mean value.

Discussion

Our results indicate a noticeable spatial dynamics of the indicators characterizing the current structure of the land fund, ecological sustainability of the territory, and differentiation of various lands in the border steppe regions of the Urals and Siberia. The distribution of the land categories in the administrative districts of the Orenburg region bordering the RK indicates a higher relative area of agricultural land (more by 3.54 percentage points, hereinafter p.p.) compared to the region as a whole (88.18%). The share of reserved lands is practically twice as much in the border zone, 71.7% of their regional area is concentrated here (22.3 out of 31.1 thousand hectares).

With regard to other land categories, a somewhat different dependence was revealed. In the border zone of the Orenburg Oblast in relation to the total area of lands within the administrative boundaries the share of lands of settlements is 2.0 p.p. lower, 0.46 p.p. lower – the share of lands of industry, energy, transport, communication and other special purpose was 0.46 p.p. lower, the share of lands of specially protected territories was 0.17 p.p. lower, the lands of forest and water fund were lower by 1.10 and 0.03 p.p. correspondingly. We noted that in the border administrative districts of the Orenburg Oblast, almost 40.0% of agricultural land and almost one third of the lands of industry, energy, transport, communications and other special purpose (29.0%), as well as the lands of specially protected territories and objects (30.9%), forest (29.3%) and water (31.0%) are concentrated. At the same time, in the total area of land within the administrative boundaries the share of lands of populated settlements is only 14.5%.

The distribution of the land categories in the administrative districts of Altai Krai that border the RK is characterized by somewhat different features. Exceeding the average regional relative values (by 0.77 p.p.) is observed here only in relation to the lands of specially protected territories and objects, 85.7% of which are concentrated in the border strip. The share of agricultural lands is very close to the Orenburg Oblast which were 67.89 and 68.66%, respectively, with a slight negative trend. Among other land categories, in contrast to the Orenburg Oblast, the border zone of Altai Krai has a smaller relative share of reserve lands and a larger share of forest and water fund lands. At the same time, here, as well as in the Orenburg Oblast, the border administrative districts are characterized by a smaller share of lands of settlements, industry, energy, transport, communication, and other special purpose (Fig. 3).

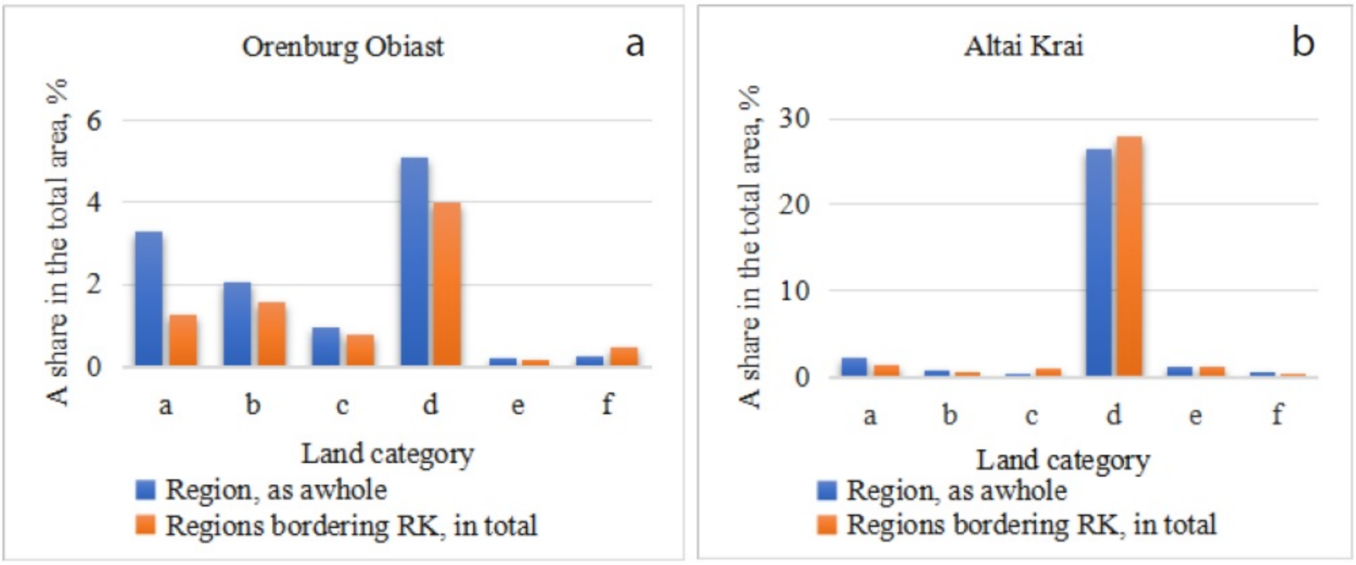

Figure 3. *Spatial variability of lands in the adjacent to the RK MOs (administrative districts) of the Orenburg Oblast (a) and Altai Krai (b), % of the total area of land within the administrative boundaries (a – lands of settlements, b – lands of industry, energy, transport, communication and other special purposes, c – lands of specially protected territories, d – lands of the forest fund, e – lands of the water fund, f – reserve lands).*

In the administrative districts of the Altai Krai border, there is a smaller share of agricultural land than in the Orenburg Oblast, which is 21.7% of the total oblast area. Only 12.7% of the settlement

Acta Biologica Sibirica
Vol 9 (2023): Acta Biologica Sibirica , 1037–1060
Articles

land, 17.0% of the land of industry, energy, transport, communication, and other special purpose, 22.1-23.3% of the land of water and forestry funds are confined to the border zone. Analysis of data on the distribution of the land fund by lands in the border administrative districts of the Orenburg Oblast indicates a larger share of agricultural lands (by 1.90 p.p.), hay fields (by 2.34 p.) and pastures (by 5.64 p.p.) in the total land area as compared to the average regional indicators. At the same time, the share of arable land, perennial plantations and nonagricultural land is lower – by 5.95-0.15-1.90 p.p., respectively. Approximately half of the total area of hay fields (49.8%), more than 40.0% of pastures, and a third of arable land (31.0%) and non-agricultural land (29.9%) are concentrated in the border areas.

In the border territories of Altai Krai, characterized by a smaller relative share of agricultural land (6.08 p.p. lower than in the Krai as a whole), a smaller share of arable land (by 4. 76 p.p.), perennial plantations (by 0.06 p.p.), hayfields (by 2.70 p.p.), relatively more pastures (by 0.07 p.p.), nonagricultural land (by 6.08 p.p.) and fallow land (by 1.38 p.p.). Furthermore, 44.4% of the fallow lands in Krai (118.1 out of 265.9 thousand ha) is located in the border zone. The results of the comparison of individual components of the complex indicator of environmental sustainability in the adjacent territories of the Russian Federation and the Republic of Kazakhstan revealed their significant territorial variability, expressed in a different combination of elements that have a favorable or negative impact on environmental components. For example, there is a significant predominance of pastures in the structure of lands in the border territories of the RK, accounting for 84.14-73.14-70.03-66.51 and 56.93% (Aktobe, West-Kazakhstan, East-Kazakhstan, Pavlodar, and Kostanay Oblasts, respectively) of the total land area within the administrative boundaries (Fig. 4).

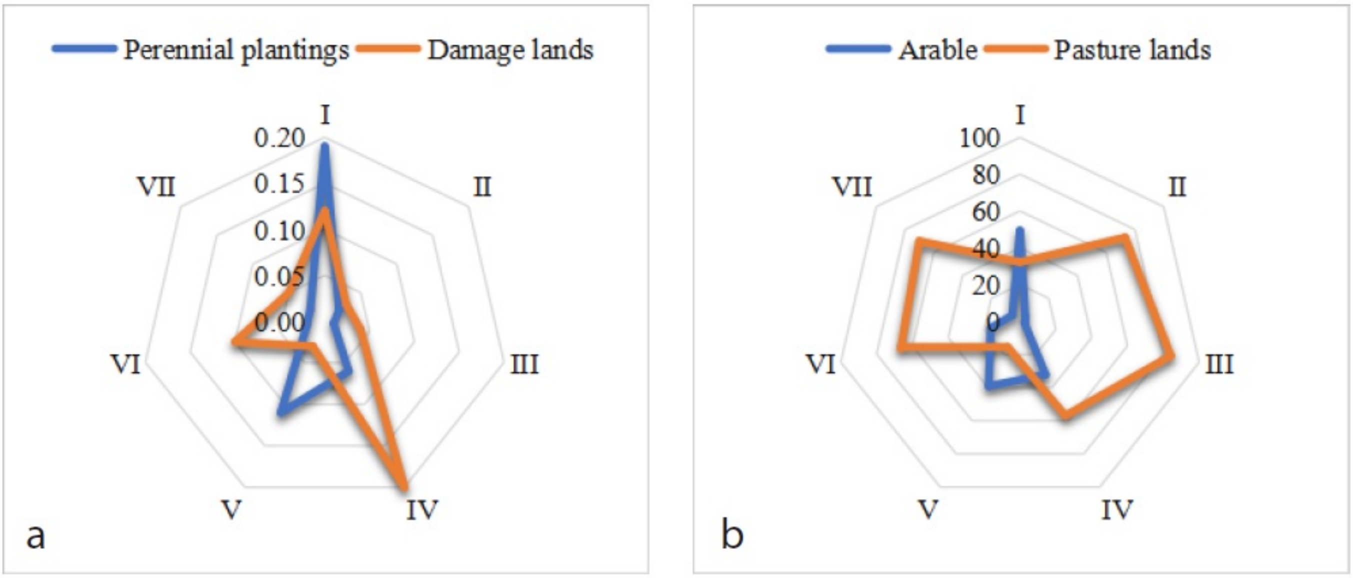

Figure 4. *Elements of the Index of Landscape Ecological Stability (ILES) in the border post-virgin regions of the Urals and Siberia and adjacent border regions of the Republic of Kazakhstan, % of the total land area within administrative boundaries (I – Orenburg Oblast, RF; II – Western Kazakhstan Oblast, RK; III – Aktobe Oblast, RK; IV – Kostanay Oblast, RK; V – Altai Krai, RF; VI – Pavlodar Oblast, RK; VII – East Kazakhstan Oblast, RK).*

In neighboring Russian territories the share of pastures in the structure of lands is much lower – 32.23% in the Orenburg Oblast and 15.45% in the Altai Krai; at the same time the share of elements of negative impact on environmental components is higher here. Therefore, the share of arable land in the structure of land in the Orenburg Oblast is approximately 50.0%, while 39.12% of the total land area is occupied by it in the Altai Krai. Among Kazakhstan's regions bordering the Russian Federation, only in Kostanay Oblast this indicator is close to the Russian one (32.11%), while in other territories it is much lower – 16.29 (Pavlodar oblast) – 5.30 (East Kazakhstan oblast) – 3.75 (West Kazakhstan oblast) – 2.36% (Aktobe oblast). Among other land categories, Russian regions are characterized by a greater share of perennial plantations and disturbed land. The above characteristics in the structure of the lands of the bordering territories of Russia and the Republic of Kazakhstan, expressed in a more favorable combination of ecological sustainability elements in the Kazakh territory, were accompanied by a higher assessment of their ecological sustainability, clearly expressed in the West, Aktobe, and East Kazakhstan Oblasts, well expressed in the Pavlodar region and conditionally stable in the Kostanay Oblast.

The assessment of environmental sustainability of the Russian border territories is much lower and corresponds to an unstable condition in the Orenburg Oblast as a whole and a conditionally stable condition in the Altai Krai. Regarding the environmental sustainability of the territory of the border administrative districts of Orenburg Oblast and Altai Krai, multidirectional trends were revealed. Therefore, in the Orenburg Oblast border zone, the average ILES value for individual districts was higher than in the Oblast as a whole by 0.29 units and corresponds to the conditionally stable state. The Dombarovsky (2.11), Kuvandyksky (1.75) and Akbulaksky (1.37) districts are characterized by the best stability indicators among the border areas. They also made the greatest contribution to improving the environmental sustainability of the territory as a whole in the border zone. The Tashlinsky, Sol-Iletsky, Ileksky, and Pervomaisky districts are characterized by the lowest environmental sustainability, 0.04-0.15 units below the average regional indicators.

The analysis of the land structure indicates a smaller relative share of arable land in the land use of administrative districts with greater environmental sustainability of the territory, amounting to 29.3 (in Dombarovsky district) and 31.1% (in Kuvandyksky district) of the total land area within the administrative boundaries, and a larger share in administrative districts with lower environmental sustainability, amounting to 41.0 (Tashlinsky), 43.2 (SolIletsky), 44.5 (Pervomaysky), and 46.4% (Ileksky). Our analysis of land structure and ILES values of the territory on the confinement of municipalities to international transport communications from the Russian Federation to the Republic of Kazakhstan allowed us to identify the trends of their stimulating influence on the expansion of production (increase in the share of arable land) and reduction in ILES, with the exception of some administrative districts with extremely limited climatic and soil resourcest.

Thus, the number of municipal districts with high ILES values includes Kuvandyksky and Dombarovsky districts, which do not have vehicle and railway checkpoints on their territory, as well as the Akbulaksky district, which is characterized by extremely unfavourable conditions for field production and is connected to the RK by the Orenburg-Aktobe highway with a multilateral vehicle checkpoint Sagarchin-Zhaisan and the Orenburg-Aktobe railway. Low ILES values are observed mainly in administrative districts adjacent to international transport communications. For example, the Orenburg-Uralsk, Orenburg-Aktyubinsk railway, and the Orenburg-Aktyubinsk highway with the Sagarchin-Zhaisan multilateral vehicle checkpoint pass through Sol-Iletsk District. The Ilek District has the Ilek-Aksai multilateral vehicle checkpoint on the Orenburg-Uralsk highway, and Pervomaisky Oblastt has two checkpoints, the multilateral vehicle checkpoint Mashtakovo-Syrym on the Samara-Uralsk highway and the bilateral vehicle checkpoint Tyoploye-Shagan on the Bugulma-Uralsk highway. The only exception is the Tashlinsky district, which does not have international transport routes on its territory, but is characterized by a high share of arable lands due to the progressive development of melon growing, with the center in the "watermelon capital of Russia" Sol-Iletsk (Sol-Iletsky district) and sunflower cultivation in large areas, which is generally typical for the whole Orenburg Oblast (Fig. 5).

Figure 5. *Visualization of land use density in the Sol-Iletsky border district of the Orenburg Oblast, an active melon growing center in Russia.*

In the Altai Krai border territories, generally characterized by a more stable ecological condition of the territory, the average value of ILES was lower than in the border territories of the Orenburg Oblast. The greatest reducing influence on its average value was exerted by the indicators of Tabunsky, Kulundinsky, and Loktevsky districts, with the lowest value among 21 administrative districts, 0.24-0.28 and 0.44 units, respectively. The value of the integrated indicator of environmental sustainability of the territory is also below the average regional values in Slavgorodsky, Klyuchevsky, and Rubtsovsky Districts. At the same time, it should be noted that in four administrative districts bordering the RK, the value of ILES is higher than the regional average by 0.03-0.19 units (Mikhailovsky, Zmeinogorsky, Burlinsky, and Tretyakovsky districts), and in the Charyshsky and Uglovsky districts it is almost twice as high (2.21-2.47).

Regarding the relationship between the ILES value and the location of municipalities in international transport communications, as well as for the administrative districts of the Orenburg Oblast, a trend of decrease of ILES decrease was revealed in administrative districts with a developed international transport network. Thus, low ILES values are observed in Slavgorodsky, Tabunsky, Kulundinsky, and Kliuchevsky districts, which have on their or adjacent territories the Kulunda-Sharbakty multilateral vehicle checkpoint on the Barnaul-Pavlodar highway and the Barnaul-Astana railway. At the same time, in some administrative districts, also territorially close to international transport communications, high ILES values were observed, indicating the presence of other, rather weighty factors. Such municipalities include, for example, Mikhailovsky and Uglovsky districts, adjacent to the Barnaul-Semey-Almaty highway with multilateral vehicle checkpoint Veseloyarsk-Auyl. In connection with a rather low assessment of environmental sustainability of the Russian territories adjacent to the RK, the dynamics of the areas of land in the composition of agricultural land, its direction (trend) and magnitude determining the complex indicator of environmental sustainability is of certain interest.

Analysis of land structure dynamics within 2006–2021 revealed a positive trend in the arable land area, as one of the most ecologically unstable landscape elements, in both border Russian regions analyzed. Furthermore, in the Orenburg Oblast, border administrative districts account for one third of the newly developed arable land during the analyzed period – 112.3 thousand hectares of 326.0 thousand hectares in the Oblast as a whole. In the administrative districts of Altai Krai bordering the RK, the increase in the arable land area is somewhat less than in the Orenburg Oblast (by 245.0 thousand hectares), whereas its third part (72 thousand hectares) is also concentrated in the border areas. Moreover, in the border areas of Altai Krai the area of fallow land has decreased by the same amount, while the area of hayfields has decreased by 0.1 thousand ha and pastures have decreased by 2.7 thousand ha. In the border areas of the Orenburg Oblast, with a similar negative trend in the hayfield area (by 0.3 thousand ha), there is also a decrease of 0.1 thousand ha in perennial plantations, which, together with the increase in arable land, additionally reduced the coefficient of ecological stability of landscapes. Only the increase in pasture area by 3.3 thousand ha contributes to some stabilization of the ecological situation, although this is clearly insufficient for a radical change in the ecological situation in the region under consideration.

Therefore, the formation of the land fund structure determines the agricultural productivity of the territories, along with the common practice of expanding the area of cultivated land under conditions of increasing demand for crop production, has strong geographical patterns that affect the landscape ecological stability in the post-virgin border regions of the Urals and Siberia.

Conclusions

We revealed a noticeable spatial dynamics of indicators characterizing the current structure of the land fund, ecological sustainability of the territory, and land differentiation in the border steppe regions of the Urals and Siberia. The border municipalities of the Orenburg Oblast are characterized by a higher relative value of the area of agricultural land (by 3.54 p.p.), agricultural land (by 1.90 p.p.), hayfields (by 2.34 p.p.) and pastures (by 5.64 p.p.) compared to the average oblast indicators, while the share of arable land, perennial plantations, and non-agricultural land is 5.95-0.15-1.90 p.p. lower, correspondingly. Here the ILES value is 1.13 that is 0.29 units higher than in the oblast as a whole (0.84, unstable) and corresponds to a conditionally stable condition.

In the Altai Krai municipalities bordering with the RK, there is an excess of the average regional relative values for the area of lands allocated for SPNA (by 0.77 p.p.), relatively more pastures (by 0.07 p.p.), nonagricultural lands (by 6.08 p.p.), and fallow lands (by 1.38 p.p.). The share of agricultural land is close to the regional average, while the share of agricultural land, arable land, perennial plantations and hayfields is by 6.08, 4.76, 0.06, and 2.70 p.p. lower than in the Krai as a whole, respectively. The average ILES value in the border municipalities (1.08, conditionally stable) is 0.09 units lower than in the Krai as a whole and 0.05 units lower than in the border municipalities of the Orenburg Oblast.

The RK regions bordering the Orenburg Oblast and Altai Krai are distinguished by a higher assessment of environmental sustainability due to a more favorable combination of elements determining ILES, in particular, due to a significant predominance of pastures in the structure of the lands (up to 56.93-84.14%). In border municipalities adjacent to international transport communications, there is a tendency to decrease ILES. To a greater extent, it is connected with the increasing share of arable lands, clearly manifested in the Orenburg Oblast and Altai Krai, especially in the territories predisposed to the production of marginal crops (sunflower and cucurbits).

The formation of an ecologically safe structure for the use of agricultural land in these regions can be considered as the main objective of improving the environmental sustainability of the territory and maintaining biological diversity. Furthermore, the concentration of production resources on highly productive land will contribute to a more effective development of modern high-tech agrotechnologies and will ensure a more efficient use of modern agricultural technologies.

Acknowledgements

The research was supported by the Russian Scientific Foundation (project "The geographical basis of a spatial development in the agricultural post-virgin regions in Ural and Siberia», No. 20-17-00069-P).

References

Akamani K (2020) Integrating deep ecology and adaptive governance for sustainable development: implications for protected areas management. Sustainability 12 (14): 5757. https://doi.org/10.3390/su12145757

Altukhov A (2009) Grain economy and Russia's food security. APK: Economics and Management 1: 3–12. Available from: https://www.elibrary.ru/item.asp?id=13754782 [In Russian]

Andhinoni G, Andhinoni FBG, Tormena CA, Braccini AL, Mendes IC, Zancanaro L, Lal R (2021) Conservation agriculture strengthen sustainability of Brazilian grain production and food security. Land Use Policy 108: 105591. https://doi.org/10.1016/j.landusepol.2021.105591

Baranov VA (2012) Environmental optimization of agroforest of the southeast of European Russia (structure, dynamics, evolution). Saratov ASP: 314. [In Russian]

Bruce AB, Farmer JR, Giroux S, Dickinson S, Chen X, Donnell MO, Benjamin TJ (2022) Opportunities and barriers to certified organic grain production on rented farmland in the U.S. Midwest state of Indiana. Land Use Policy 122: 106346. https://doi.org/10.1016/j.landusepol.2022.106346

Canelas JV, Pereira HM (2022) Impacts of land-use intensity on ecosystems stability. Ecological Modelling 472: 110093. https://doi.org/10.1016/j.ecolmodel.2022.110093

Chupina IP, Simachkova NN, Zhuravleva LA, Fateeva NB, Petrova LN (2023) On the problem of state management of land resources in Russia. Moscow Economical Journal 8(6): 267. https://doi.org/10.55186/2413046X_2023_8_6_267 [In Russian]

Dokuchaev VV (1953) Our steppes before and at the present [Nashi stepi prezhde i teper']. Selkhozgiz, Moscow. Available from: http://www.savesteppe.org/docs/Dokuchaev.pdf [In Russian]

Dospekhov B A (1985) Methodology of field experience (with the statistical processing of the results of the study). Agroporomizdat, Moscow. Available from: https://www.studmed.ru/view/dospehov-ba-metodika-polevogo-opyta_9733259bddc.html [In Russian]

Eeswaran R, Nejadhashemi AP, Krodo J, Curtis ZK, Adhicari U, Liao H, Li S-G, Hernandes-Suarez JS, Alves FC, Raschke A, Jha PK (2021) Quantification of resilience metrics as affected by conservation agriculture et a watershed scale. Agriculture, Ecosystems and Environment 320: 107612. https://doi.org/10.1016/j.agee.2021.107612

Garbelini LG, Debiasi H, Balbinon AA (ju), Franchini JC, Coelho AE, Telles TS (2022) Diversified crop rotations increase the yield and economic efficiency of grain production systems. European Journal of Agronomy 137:126528. https://doi.org/10.1016/j.eja.2022.126528

Glas'ev SYu (2019) Global economic crisis as the process of the technological knowledge' change Issues of economics 3: 26-38. https://www.elibrary.ru/item.asp?id=11724018 [In Russian]

Glukhovskaya MY (2017) Analysis of ecological sustainability and regional territory stability on the example of Orenburg region. Bulletin of Orenburg State University 4 (204): 53–61. Available from: https://www.elibrary.ru/item.asp?id=29880328 [In Russian]

Gulyanov YuA, Chibilev (jr) AA, Chibilev AA, Levykin SV (2022) Problems of steppe land use adaptation to anthropogenic and climatic changes (the case of Orenburg oblast). Izvestiya Rossiyskoy Akademii Nauk (Seria Geographicheskaya) 86(1): 28–40. https://doi.org/10.31857/S258755662201006X [In Russian]

Gulyanov Yu A, Chibilev A A (2023) Rain-fed agriculture in the steppe and forest-steppe zone of Ural River basin and the adaptation of agricultural technologies to changing moisture availability as a way to preserve surface water resources. South of Russia: Ecology, Development 18(1): 117-125. https://doi.org/10.18470/1992-1098-2023-1-117-125 [In Russian]

Karataev M, Clarke M, Salnikov V, Bekseitova R, Nizamova M (2022) Monitoring climate change, drought conditions and wheat production in Eurasia: the case study of Kazakhstan. Heliyon 8 (1): e08660. https://doi.org/10.1016/j.heliyon.2021.e08660

Kastner T, Matej S, Forrest M, Gingrich S, Haberl H, Hiscler T, Krausmann F, Lasslop G, Niedertscheider M, Plutzar C, Schwarzmuller F, Steinkamp J, Erb K (2021) Land use intersification increasingly drives the spatiotemporal patterns of the global human appropriation of net primary production in the last century. Global Change Biology 28 (1): 307–322. https://doi.org/10.1111/gcb.15932

Kazakhstan extends restrictions on grain import into the country and introduces new sanctions (2023) Available from: https://www.bfm.ru/news/534673 (accessed 28.10.2023). [In Russian]

Kireyenka NV, Kandratsenka SA (2016) Prospects for strengthening food security of the Republic of Belarus. Proceeding of the National Academy of Sciences of Belarus. Agrarian Series 4: 21–31. Available from: https://www.elibrary.ru/download/elibrary_28351959_53494546.pdf [In Russian]

Kiryushin VI (2004) Ecologically sustainable price for agricultural landscapes. Izvestiya of the Orenburg State Agrarian University 4(4): 9–12. Available from: https://www.elibrary.ru/item.asp?id=15269803 [In Russian]

Klementova EN, Geinige V (1995) The assessment of ecological stability of agricultural landscape. Melioration and Water Management 5: 33–34. [In Russian]

Klyushin PV, S Hormanov AH (2015) Generalised estimation pressure land loads on agricultural lands Kabardino-Balkar Republic. The modern issues of lands use. GUZ, Moscow. Available from: https://www.elibrary.ru/item.asp?id=23931410 [In Russian]

Kochurov BI (2005) Modern land management and land use management in Russia. In: Sustainable development of agriculture and rural areas: foreign experience and problems of Russia. Creativity of scientific publications of the Scientific press Ltd., Moscow, 322–334. [In Russian]

Kolodina NF (2015) Methodological study the situation of food security in the region in terms of import substitution. Vestnik of Orenburg State University 13 (188): 41–47. Available from: .ru/item.asp?edn=vtnuwt [In Russian]

Korotkikh AA (2019) Grain Exports? USA and Canada: Economics, Politics, Culture 49 (4): 108–123. https://doi.org/10.31857/S032120680004362-2 [In Russian]

Kuznecova MA (2020) Improving the efficiency and rational use of land in the development of transport hubs. Journal of Economy and Entrepreneurship 3 (116): 360–364. https:/doi.org/10.34925/EIP.2020.116.3.074 [In Russian]

Lopatiuk NO (2014) The state prospects of market of grain trends are in Ukraine. Economic Studios 4 (4): 181–186. Available from: https://www.elibrary.ru/item.asp?id=23077953

Lu D, Lu Yi, Gao G, Sun S, Wang Yi, Fu B (2024) A landscape persistence-based methodological framework for assessing ecological stability. Environmental Science and Ecotechnology 17: 100300. https://doi.org/10.1016/j.ese.2023.100300

Malanson GP, Talal ML, Pansing ER, Franklin SB (2021) Vegetation ecology with antropic drivers and consequences. Progress in Physical Geography: Earth and Environment 45 (3): 446–459. https://doi.org/10.1177/0309133321999371

Materinska OA (2013) The potential for production and export of grain in Ukraine. Economica APK 10(228): 049–053. Available from: https://www.elibrary.ru/item.asp?id=20377092

Meade B, Puricelli E, McBride W, Valdes C, Hoffman L, Foreman L, Dohlman E (2016) Corn and soybean production costs and export competitiveness in Argentina, Brazil, and the United States. USDA Economic Information Bulletin 154: 52. Available from: https://papers.ssrn.com-/sol3/papers.cfm?abstract_id=2981675

Merlos FA, Monzon JP, Mercau JL, Taboada M, Andrade FH, Hall AJ, Jobbady E, Cassman KG, Grassini P (2015) Potential for crop production increase in Argentina through closure of existing yield gaps. Field Crops Research 184: 145–154. https://doi.org/10.1016/j.fcr.2015.10.001

Mizanbekova S, Kalykova B, Mizanbecov I (2018) Issues of sustainable development of grain product subcomplex of Kazakhstan. Problems of Agrimarket 2: 139–147. Available from: https://www.elibrary.ru/item.asp?id=35418139

Nepoklonov VB, Khabarova IA, Khabarov DA (2018) Monitoring and rational use of agricultural land of Krasnodar territoru. Vestnik of the Siberian State University of Geosystems and Technologies (SSUGT) 23(1): 167–178. Available from: https://www.elibrary.ru/item.asp?id=32834057 [In Russian]

Nikouei A, Asgharipour MR, Marzban Z (2022) Modeling land allocation to produce crops under economic and environmental goals in Iran: a multi-objective programming approach. Ecological Modelling 471: 110062. https://doi.org/10.1016/j.ecolmodel.2022.110062

Parparov A, Gal G (2016) Quantifying ecological stability: from community to the lake ecosystem. Ecosystems 20 (5): 1015–1028. https://doi.org/10.1007/s10021-016-0090-z

Pince Z, Decsi B, Kardos MK, Kern Z, Kozma Z, Pasztor L, Acs T (2022) Changing pat- terns of soil water content and relationship with national wheat and maize production in Europe. European Journal of Agronomy 140: 126579. https://doi.org/10.1016/j.eja.2022.126579

Popytchenko LM (2021) Efficiency of use bioclimatic resources of agrolandscapes of Donbass. Scientific Bulletin of Lugansk State Agrarian University 1 (10): 77–84. Available from: https://www.elibrary.ru/item.asp?id=54687613 [In Russian]

Procop P (2020) Remote sensing of severely degraded land: Detection of long-term landuse changes using high-resolution satellite images on Meghalaya Plateau, northeast India. Remote Sensing Applications. Society and Environment 20: 100432. https://doi.org/10.1016/j.rsase.2020.100432

Shao W, Zhang Z, Guan Q, Yan Y, Zhang J (2024) Comprehensive assessment of land degradation in the arid and semiarid area based on the optimal land degradation index model. Catena 234: 107563. https://doi.org/10.1016/j.catena.2023.107563

Shundalov BM (2023) Rating assessment of cultivation of grain and leguminous crops in Belarus. Vestnik of the Belarusian State Agricultural Academy 1: 17–21. Available from: https://www.elibrary.ru/download/elibrary_50394946_60877358.pdf

Shuvarin MV, Savrukov NT (2019) Not iridescent prospects of the Russian village. Bulletin of NGIEI 4 (95): –13. Available from: https://www.elibrary.ru/item.asp?id=37536662 [In Russian]

Siberian regions reduce grain exports to Kazakhstan (2023) Available from: https://www.interfax-russia.ru/siberia/news/sibirskie-regiony-snizhayut-eksport-zerna-v-kazahstan-ekspert (accessed 28.10.2023) [In Russian]

Simmons AT, Cowie AL, Brock PM (2020) Climate change mitigation for Australian wheat production. Science of The Total Environment 725: 138260. https://doi.org/10.1016/j.scitotenv.2020.138260

The State (National) Report on the state and use of lands (2022) Available from: https://rosreestr.gov.ru/activity/gosudarstvennoe-upravlenie-v-sfere-ispolzovaniya-i-okhrany-zemel/gosudarstvennyy-natsionalnyy-doklad-o-sostoyanii-i-ispolzovanii-zemel-rossiyskoy-federatsi/ (accessed 14.06.2023) [In Russian]

Uprety Ya, Asselin H, Bergeron Yv, Doyon F, Boucher Je-F (2012) Contribution of traditional knowledge to ecological restoration: practices and applications. Ecoscience 19 (3): 225–237. https://doi.org/10.2980/19-3-3530

Wang J, Wang J, Zhang J (2023) Spatial distribution characteristics of natural ecological resilience in China. Journal of Environmental Management 342: 118133. https://doi.org/10.1016/j.jenvman.2023.118133

Wang L, Zheng W, Tang L, Zhang S, Liu Yu, Ke X (2021) Spatial optimization of urban land and cropland based on land production capacity to balance cropland protection and ecological conservation. Journal of Environmental Management 285: 112054. https://doi.org/10.1016/j.jenvman.2021.112054

Wu X, Xiao X, Yang Z, Wang J, Steiner J, Bajgain R (2021) Spatial-temporal dynamics of maize and soybean planted area, harvested area, gross primary production, and grain production in the Contiguous United States during 2008-2018. Agricultural and Forest Meteorology 297: 108240. https://doi.org/10.1016/j.agrformet.2020.108240

Zhang X, Jin X, Liang X, Ren J, Han B, Liu J, Fan Y, Zhou Y (2022) Implications of land sparing and sparing for maintaining regional ecosystem services: An empirical study from a suitable area for agricultural production in China. Science of the Total Environment 820: 153330. https://doi.org/10.1016/j.scitotenv.2022.153330

Zonn IS, Trofimov IA, Shamsutdinov ZSh, Shamsutdinov NS (2004) Lands resources of Russia arid territories. Arid Ecosystems 10 (22–23): 87–101. Available from: https://www.elibrary.ru/item.asp?id=13050580 [In Russian]